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BIO-ACOUSTICS SPECIAL STUDY NO. 34-018-75

EVALUATION OF THE ENVIRONMENTAL IMPACT AND RECOMMENDED CONTROL MEASURES TO REDUCE THE NOISE GENERATED FROM MILITARY HELICOPTER OPERATIONS AT THE McGUIRE VETERANS ADMINISTRATION HOSPITAL RICHMOND, VIRGINIA

OCTOBER 1974

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DEPARTMENT OF THE ARMY
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An evaluation was made to determine the extent to which noise from helicopter operations at the McGuire Veterans Administration Hospital helipad could affect nearby residential areas and the hospital activities. No adverse impact was found and little or no annoyance is anticipated. Recommendations were made to further minimize the chance of annoyance.

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1. REFERENCES.

a. TM-5-365, Civil Engineering Planning and Programming; Land Use Planning with Respect to Aircraft Noise, 1 October 1964.

b. The Noise Control Act of 1972, PL95-574 (42 USC 4901, et. seq.).

c. Letter, AFKA-RR-CK, Headquarters, 80th Division Tng, United States Army Reserve, 18 April 1974, subject: Request for an Environmental Impact Survey.

2. PURPOSE. To evaluate the environmental noise impact of helicopter operations at the McGuire Veterans Administration (VA) Hospital helipad, Richmond, Virginia.

3. GENERAL.

a. Background. The Noise Control Act of 1972 states that "... inadequately controlled noise presents a growing danger to the health and welfare of the Nation's population ..." (reference paragraph 1b). Accordingly, the US Army Environmental Hygiene Agency (USAEHA) was requested to evaluate the environmental impact of noise from proposed helicopter operations associated with the McGuire VA Hospital helipad. This helipad is to be used for both medical evacuation and transportation of the 80th Division (Div) Training (Tng) staff personnel whose headquarters are located at the Hospital. There are no training missions involved with the use of this helipad. Approval for the helipad has already been granted by the Federal Aviation Administration (FAA) and the Fort Lee Safety Office; however, it was also the desire of the aviation personnel at the 80th Div Tng to conduct an investigation to assure that there will be no adverse effects with regard to excessive noise intruding into the community surrounding the hospital.

b. Personnel Contacted. The following key personnel were contacted and/or consulted during the conduct of this study:

(1) CPT Jimmy L. Duncan, Flight Facilities Advisor, 80th Div Tng.

(2) MSG Matthew F. Newsome, Senior Enlisted Aviation Advisor, 80th Div Tng.

(3) Mr. Mark Furman, Dispatcher, 97th ARCOM Sub-Flight Facility.

c. Aircraft Activity. UH-1 and OH-58 type aircraft will utilize the McGuire VA Hospital helipad. Aircraft operations will be restricted to daytime hours (0800-1800 hours) with most air operations occurring between 1100 and 1400 hours. The majority of this air activity will occur on the weekends. Analyses in this investigation are based upon a maximum of six operations in any one day for each type of aircraft on each pattern with a projected monthly maximum of 60 operations.* All operations will be flown using Visual Flight Rules (VFR).

d. Helipad. The helipad is a 100-sq ft grass-turf pad on level terrain, marked in the center by a white, metal letter H. It is located in the northeast corner of the McGuire VA Hospital property (see Figure 1, Appendix A). The pad is approximately 500 ft from both the nearest hospital activity and the nearest residence.

e. Start-up and Maintenance Activity. Aircraft run-up, start-up, and maintenance activities are performed at the airfield from which the helicopter originates. Occasionally start-up from a shutdown condition will be performed on the McGuire helipad itself.

f. Flight Patterns. The aircraft flight patterns for the helipad are depicted in Figure 1, Appendix A. A description of these patterns is as follows:

(1) Sighting Pattern. Pilots flying on this approach make visual contact with the helipad and then maneuver the aircraft into the proper position for a VFR landing along one of the designated patterns. This circling maneuver is initiated approximately one-half to three-quarters of a mile from the helipad. The helipad is circled once at this distance at an altitude of about 1000-1300 ft above ground level (AGL) prior to landing.

(2) Main Pattern. This pattern is initiated from the circling maneuver of the Sighting Pattern at an altitude of approximately 1000 ft AGL. The helicopter flies parallel to Hopkins Road which forms the eastern boundary of the Hospital property. A path just inside the eastern property line is then followed to touchdown on the helipad. The aircraft is at an altitude of approximately 500 ft AGL as it passes over high tension power lines along Chalfont Drive. Take-off follows the same path as that described for landing.

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* An operation is defined as an approach or departure from the McGuire VA Hospital helipad.

(3) Alternate Pattern. This pattern will be used very infrequently under specific weather conditions which would preclude the use of the Main Pattern. The Alternate Pattern is also initiated at an altitude of about 1000 ft AGL from the Sighting Pattern. Aircraft flying on this pattern follow the northern property line parallel to McGuire Drive. The aircraft then doglegs around the water tower descending to an altitude of 500 ft AGL. Descent is then continued until touchdown. Take-off from the helipad is along the same route.

g. Land Use. The McGuire VA Hospital property is surrounded primarily by residential areas. Single family dwellings are located to the north, east, and west of the property, while multifamily housing is located to the south. Beyond these residential areas are large industrial and undeveloped tracts of land situated approximately one-half mile to the southeast and a commercial land use area approximately one-half mile to the northwest along Belt Boulevard. Old Broad Rock School, located on Catalina Avenue, is the only school in the vicinity of the McGuire VA Hospital. The school lies approximately one-third mile from the Hospital property and 1 mile from the helipad location. Future land use in the vicinity will remain virtually unchanged with the exception of possible development of the existing undeveloped land by industry. All three aircraft flight patterns associated with the helipad will require the helicopters to fly over residential areas.

h. Guidelines.

(1) The guidelines used in this assessment for evaluating the acceptability of aircraft noise attributable to operations from the proposed use of the McGuire VA Hospital helipad were based on Federal criteria. The guidelines included those used by the FAA,[1 2] Department of Housing and Urban Development (HUD),[3] and Department of the Army procedures established in TM-5-365 (reference paragraph 1a) (Table 1, Appendix B). The main constituent of the assessment procedures is the use of the Composite Noise Rating (CNR) contours. The CNR analysis is an accepted procedure for evaluating aircraft noise and has been used by the Department of Defense since 1965. The validity of the CNR system has been verified in a number of

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[1] Dwight Bishop, "Helicopter Noise Characteristics for Heliport Planning," Technical Report prepared under contract for the FAA (March 1965).

[2] Robert L. Paullin, "The Federal Aviation Administration and Aircraft Noise Control," presented at a conference on Atmospheric Noise Pollution Measures for Its Control, College of Engineering, University of California, Berkeley, CA (17-21 June 1968).

[3] US Department of Housing and Urban Development Circular 1390.2, Noise Abatement and Control: Department Policy, Implementation, Responsibilities and Standards (4 August 1971).

independent studies.[4] The CNR rating scheme divides the land areas surrounding the facility into a number of noise descriptor zones, each of which is capable of projecting information on the potential adverse noise impact from aircraft operations at the helipad. There are no existing local or state guidelines or standards establishing maximum permissible aircraft noise levels.

(2) The impact of noise upon selected noise sensitive land areas was assessed by comparing the existing ambient noise levels in these areas with the projected levels of intruding helicopter noise. In addition, projections of the magnitude of helicopter noise intruding into schools and residences in the vicinity and into the Hospital were compared to criteria of desirable noise levels for interior work spaces (Table 6, Appendix B[5]).

4. PROCEDURES.

a. Helicopter Noise Emission Data Base. Quantitative noise emission data on the OH-58A and UH-1 were available from the noise data base at USAEHA. These data had been obtained in previous studies specifically designed for use in the assessment of aircraft noise impact upon communities surrounding military installations. The noise data are required in order to estimate aircraft noise levels directly under and off to each side of each flight path. The noise information is used to develop generalized CNR contours after adding corrections for those operational factors that most influence community reactions to aircraft noise. Noise information was gathered during controlled aircraft operations. In these tests helicopter noise was measured during normal cruise conditions at a constant airspeed at altitudes of 500, 1000, 1500, and 2000 ft above ground level. In addition, measurements were also made for controlled take-offs, landings, and run-ups. Information relative to the conduct of the data base studies is contained in Appendix C.

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[4] Tracor Incorporated, "Community Reaction to Airport Noise," Vol 1, Technical Report prepared under contract for the National Aeronautics and Space Administration (July 1971).

[5] L. L. Beranek, et al., "Preferred noise criterion (PNC) curves and their application to rooms," Journal of the Acoustical Society of America, 50, 1223-1228 (1971).

b. Ambient Noise Measurements.

(1) General. A characteristic of urban noise is that it is not steady, but fluctuates in magnitude as a function of time. At all locations within a community, the noise levels vary considerably over a wide range. At one moment a location may be predominantly quiet, while at another instant, it may be relatively noisy (due to a vehicle pass-by, an aircraft flyover, etc.). Therefore, the noise environment at a particular location cannot be described by a single quantitative decibel level since noise levels continuously vary over time. Instead, the assessment of the noise environment at a particular location requires a statistical approach evaluating the whole time fluctuating pattern of the noise. To account for these variations and to assess urban noise in a consistent and practical manner, it has become standard acoustical practice to determine the sound levels exceeded 90, 50, and 10 percent of the time, and designate these levels as L_{90}, L_{50}, and L_{10}, respectively. All sound levels are A-weighted since this numerical rating has been found to have excellent correlation with human subjective judgment of the annoyance of noise.[6] L_{90} represents the background or residual noise level, L_{50} the average level, and L_{10} the peak level from individual noise intrusions. L_{10}-L_{90} describes the general noise climate of an area.[7] An assessment of the impact of an intruding noise, such as aircraft flyovers, can be made by comparing the intrusive noise levels from aircraft activity against the existing ambient noise levels at designated locations. Thus, a very sensitive measure of acceptability/unacceptability is to quantify the existing ambient levels in terms of L_{90}, L_{50}, and L_{10}, and determine if helicopter operations will cause these levels to be exceeded for a significant period of time.

(2) Community Noise Measurement Procedures. To insure representative environmental noise sampling, magnetic tape recordings of the existing ambient noise levels were taken at five measurement locations in the vicinity of the McGuire VA Hospital during those daytime hours (0800-1800 hours) in which the helicopters operate. No noise measurements were taken during hours of peak ground vehicular traffic since the resulting high noise levels would tend to increase the overall ambient and, therefore, prohibit accurate assessment of the noise impact under worst possible case or most quiet ambient conditions. Five 12-minute samples were taken at each site. This sampling procedure permitted an approximate accuracy of ±1 dB(A) for L_{10} and L_{50} measurements.[8]

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[6] Theodore J. Schultz, "Noise Assessment Guidelines: Technical Background," US Department of Housing and Urban Development Report No. TE/NA 172 (1971).
[7] Anon., "Community Noise," Environmental Protection Agency Report No. NTID 300.3 (1971).
[8] James F. Yerges and John Bollinger, "Manual traffic noise sampling - can it be done accurately?" Sound & Vibration, 7(12), 23-30 (1973).

(3) Community Noise Measurement Sites. To quantitatively compare existing outdoor ambient noise within the vicinity of McGuire VA Hospital to the noise intruding from helicopter operations, ambient noise recordings were gathered at five monitoring sites selected within residential and noise sensitive areas adjacent to aircraft approach or departure patterns (Figure 1, Appendix A). No measurement locations were situated near major ground vehicular thoroughfares.

(a) Site 1: situated on the helipad itself on the Hospital grounds.

(b) Site 2: situated at the corner of Stockton Street and McGuire Street behind the McGuire Park Methodist Church, directly under the Alternate Pattern.

(c) Site 3: situated on Catalina Drive in front of Old Broad Rock Elementary School, directly under the Sighting Pattern.

(d) Site 4: situated approximately 200 ft from the intersection of Hopkins Road and Chalfont Drive near the high tension power lines, approximately 200 ft from the ground projection of the Main Pattern.

(e) Site 5: situated at the intersection of Laurelbrook Street and Bangle Street, directly under the Sighting Pattern.

(4) Instrumentation.

(a) Data Collection. Bruel and Kjaer (B&K) precision sound level meters (Type 2209), tripod mounted 5 ft AGL, with 1/2-inch microphones (Type 4134), and windscreens (Type UA 0057) were used for monitoring ambient noise. Tape recordings for laboratory analysis were made using Nagra IV-SJ magnetic tape recorders. The recording system was field calibrated using B&K pistonphones (Type 4220). A reference calibration tone was put on each magnetic tape.

(b) Data Reduction. Tape recorded data were reduced in the laboratory using a B&K graphic level recorder (Type 2305) coupled to a B&K statistical distribution analyzer (Type 4420) with windows of 5-decibel range. The sampling rate was 10 samples/second.

5. FINDINGS.

a. Helicopter Noise Emission. Noise data were analyzed in terms of dB(A) as a function of aircraft altitude during level flyovers, take-offs and landings. Figures 2 and 3, Appendix A, are graphs of the mean dB(A) values, and the means plus two times the average standard deviation above the means*

$$dB(A) = \bar{X} + \sum_{i=1}^{n} \frac{2s_i}{n} \quad (1)$$

as a function of altitude for each type of aircraft. The graphs were calculated utilizing standard methodology for linear regression analysis.[9] Note that the noise level data obtained directly under the flight path tend to approximately follow the acoustical law of spherical divergence in that there is a reduction of about 6 decibels per doubling of slant distance. In addition, sideline noise measured 500 ft normalized center distance to the flight path was found to be 1 to 5 decibels greater in magnitude than the interpolated noise levels at locations directly under the aircraft for the equivalent slant distances investigated (559 ft, 707 ft, 1118 ft, and 1581 ft). This effect appears to be most prominent at lower overflight altitudes and is attributable to directivity factors of helicopter noise generation. At higher flight altitudes where angular differences between the aircraft and points directly underneath and 500 ft to the side of the flight path become negligible, the directivity effects disappear. These effects, however, may reappear at sideline distances greater than 500 ft during high altitude aircraft flyovers. Differences between sideline noise levels versus noise measured directly underneath the flight path during the OH-58 tests were found to be insignificant and, therefore, were not included in Figure 3, Appendix A. Figures 4 and 5, Appendix A, calculated in the same manner as the previous figures, are the corresponding plots of the lines of best fit for take-off operations. As expected, sound levels were inversely related to altitude. Due to differences in power settings, the magnitude of the noise levels generated during take-off operations are lower than the levels for normal cruise. Figures 6 and 7, Appendix A, show the noise data for helicopters during landing operations. Again, noise levels are inversely related to altitude.

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[9] Allen L. Edwards, Statistical Methods, Holt, Rinehart, and Winston, Inc. New York (1967).

* The data used to estimate noise levels at various distances from the aircraft are based upon values two standard deviations above the calculated means. These values account for a greater proportion of the variability of the data than the mean values and allow assessment of the environmental noise impact under worst possible conditions. A more detailed rationale for this approach is presented in the discussion.

b. Construction of CNR Contours.

(1) A chart for determining the response of residential communities to aircraft noise from calculated CNR is shown in Table 1, Appendix B. These guidelines predict the average community response to be expected and were derived as a result of numerous surveys of communities exposed to aircraft noise. Factors such as type and duration of the noise exposure, associations, psychological attitudes, socio-economic status, nature of activity into which the noise intrudes, as well as economic dependence, all affect to varying degrees the magnitude of community response. In applying Federal guidelines, the analytical procedure presented in TM-5-365 was followed except for two factors:

(a) Perceived noise levels (PNL) in decibels were obtained by adding 13 decibels to the dB(A) measurements.[10]

(b) Instead of adding various adjustment factors to the PNL's for time of day, percent utilization of flight paths, and the number of aircraft operations, the equation[11]

$$CNR = PNL\ max + 10 \log (Nd + 16.7\ Nn) - 12$$

where PNL max = maximum dB(A) + 13 (2)

Nd = number of daytime (0700-2200 hours) operations for each type of aircraft.

Nm = number of nighttime (2200-0700 hours) operations for each type of aircraft.

was used. This equation provides a more realistic assessment of the impact of aircraft noise than the procedure presented in TM-5-365. In order to determine the geographic locations of equal CNR contours, it is necessary to rearrange the above equation to derive the dB(A) noise contour corresponding and equivalent to any given CNR contour. Thus,

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10 Dwight Bishop, "Judgments of the relative and absolute acceptability of aircraft noise," Journal of the Acoustical Society of America, 40, 108-122 (1966).

11 Bio-Acoustics Special Study No. 34-030-73/74, Environmental Noise Impact, Tri-Service Incinerator Facility, Walter Reed Army Medical Center Annex, Silver Spring, Maryland (January 1974).

dB(A) = CNR - 10 log (Nd + 16.7 Nn) - 1

for CNRs of 115 (Zone 3) and 100 (Zone 2) (3)

dB(A) = 114 - 10 log (Nd + 16.7 Nn), and

dB(A) = 99 - 10 log (Nd + 16.7 Nn), respectively.*

Due to the absence of nighttime operations, these equations reduce to:

dB(A) = 114 - 10 log Nd (4)

and

dB(A) = 99 - 10 log Nd. (5)

The dB(A) values equal to CNR 100 and CNR 115 are summarized in Table 2, Appendix B.

(2) It has been contended that some adverse community response may occur in residential areas situated within a CNR 90-100 zone,[12] and that the real compatibility of a CNR 90-100 with residential dwellings is questionable.[13] Thus, a CNR 90 contour may be more representative of an area which might be adversely impacted and, therefore, was constructed for this evaluation. The dB(A) contour equivalent to the CNR 90 contour is:

dB(A) = 89 - 10 log Nd (6)

The dB(A) value equivalent to CNR 90 is also contained in Table 2, Appendix B.

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[12] Anon., "Aircraft Noise Impact: Planning Guidelines for Local Agencies," HUD Report TE/NA-472 (1972).

[13] Karl D. Kryter, The Effects of Noise on Man, Academic Press, New York (1970).

* A value of 20 was subtracted from the calculated dB(A) value for run-ups to make them equivalent to the CNR's for flyover.

(3) The horizontal ground distance for the dB(A) contours was plotted as a function of the direct distance from the aircraft to a ground location (Figures 2-7, Appendix A), and aircraft altitude at any point along the flight paths (Figure 1, Appendix A). Levels in dB(A) as a function of distance to the aircraft for distances not included in Figures 2-7, Appendix A, were calculated on the basis of a 6-decibel reduction per doubling of distance to account for spherical divergence, and a 1/2 dB reduction per 1000 ft to account for sound absorption.* Noise measurements taken 2800 to 3200 ft from the aircraft during run-up operations indicate an additional 3 decibels of excess attenuation presumably due to ground attenuation during these run-up activities.[14] Results in the form of noise sensitivity CNR zone contours for maximum helicopter activity were superimposed on a map of the surrounding area (Figure 8, Appendix A).

(4) The US Environmental Protection Agency has recently developed a guideline on a uniform methodology for quantitatively describing environmental noise.[15] This methodology, the day-night average sound level (L_{dn}), is intended to supplement other existing aircraft noise descriptor systems including the CNR and Noise Exposure Forecast (NEF). A discussion of the L_{dn} descriptor system and its relation to the CNR system used in this report is contained in Appendix D.

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[14] Bio-Acoustics Special Study No. 34-036-74/75, Evaluation of Environmental Impact of Noise from Rotary-Wing Aircraft Operations, Los Alamitos Naval Air Station, Los Alamitos, California (4-15 February 1974).

[15] US Environmental Protection Agency, "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety," Report No. 550/9-74-004 (March 1974).

* The value for sound absorption was chosen based upon the fact that the critical frequency bands for the aircraft investigated, after A-weighting, are in the 250-1000 Hertz range. According to Harris, sound absorption values for this frequency region at a temperature of 75°F and 50 percent relative humidity range from 0.25 to 1 dB/1000 ft. Cyril M. Harris, "Absorption of sound in air versus humidity and temperature," Journal of the Acoustical Society of America, 40(1) (1966).

c. Existing Ambient Noise Levels.

(1) The community noise sampling schedule was designed to evaluate the existing ambient noise during the anticipated hours of helipad operation. Therefore, a total of 60 minutes of daytime ambient noise data was collected at each of the five sites. The cumulative statistical distribution of the outdoor noise levels at the monitoring sites is presented in Table 3, Appendix B, in the form of L_{10}, L_{50}, and L_{90} values interpolated to the nearest decibel.

(2) Traffic noise and school children playing in the vicinity during the sampling periods were the predominant noise sources within the communities surrounding the McGuire VA Hospital. The residual (L_{90}) and median (L_{50}) noise levels were controlled primarily by ground vehicular traffic on major thoroughfares in the vicinity. The intensive (L_{10}) values were determined primarily by vehicle pass-by and other noise sources (children, barking dogs, etc.) in the immediate vicinity of the monitoring locations. The small spread in variability (L_{10} - L_{90}), found at all monitoring locations, further characterize the community noise environment as generally nonfluctuating. The ambient noise levels reported in Table 3, Appendix B, are typical of those normally found in most urban or suburban residential areas.[7]

d. Helicopter Noise Impact.

(1) Cumulative Impact.

(a) The calculated CNR contours are depicted in Figure 8, Appendix A. Note that these contours represent conditions of greatest possible noise exposure (i.e., maximum operations and noise levels two standard deviations above the mean). Analysis of these data indicates that the maximum CNR values would occur from only UH-1 helicopter operations at the helipad.

(b) CNR Zone 3 areas are confined to the immediate vicinity of the helipad. No Zone 3 area extends into land used for residential or other noise sensitive use.

(c) A CNR Zone 2 condition exists for all helicopter operations flown at altitudes less than 270 ft AGL. It must be noted that the CNR contour calculations were based on worst case conditions; therefore, UH-1 noise levels which are greater than OH-58 levels were used. Thus, a Zone 2 area

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[7] Anon., "Community Noise," US Environmental Protection Agency Report No. NTID 300.3 (1971).

was found to extend as a corridor along the flight paths for all operations at or below 270 ft AGL while approaching or taking off from the helipad. This CNR Zone 2 area is confined within the McGuire VA Hospital grounds; however, the area does not encompass the spinal cord ward, the closest hospital activity to the helipad. No Zone 2 conditions will extend into any noise sensitive areas from helicopter operations associated with the McGuire VA Hospital helipad.

(d) A CNR Zone 90 area extends as a corridor along all flight patterns for helicopters flying below approximately 600 ft AGL. This CNR Zone 90 extends approximately 400 ft into residential areas bordering the hospital grounds to the north and east. The CNR 90 area also includes a small portion of the spinal cord ward, but no other hospital activity.

(2) Impact of Single-Event Flyovers.

(a) Outdoor. Comparisons of intruding noise levels attributable to UH-1 helicopter operations with the existing ambient noise levels near the school, hospital, and residences are listed in Table 4, Appendix B. Note that at some locations the noise intrusion above the ambient may be significant depending upon the normal fluctuations in background noise levels. However, due to the small number of helicopter operations, the on-time of the noise intrusions will be of little consequence and do not represent an adverse impact interfering with school or residential activities.

(b) Indoor. Noise levels attributable to helicopter flyovers intruding into the interior spaces of the school, hospital, and residential sites monitored are depicted in Table 5, Appendix B. Attenuation in levels of 15 dB and 25 dB was assumed for building windows opened and closed, respectively.[15] Comparison with criteria for desirable continuous noise levels for interior spaces (Table 6, Appendix B) reveals that moderate noise intrusions may occur during helicopter flyover at each site when building windows are open. However, with windows closed, little or no noise interference will occur with sleeping, relaxing, listening conditions, or other normal activities at any location. Note that comparison of the helicopter noise with the existing ambient noise levels (L_{10} and L_{90}) indicates that there will be little intrusion attributable to helicopter operations. Due to the relatively small number of operations on each flight path, most of the noise intrusions will be of little consequence, totaling only a few minutes per month. Thus, noise from helicopter activities associated with the McGuire VA Hospital helipad will not represent an adverse impact disrupting residential or school activities.

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16 Anon., "A Study - Insulating Houses from Aircraft Noise," prepared under contract by Bolt, Beranek, and Newman, Inc., for the Department of Housing and Urban Development.

6. DISCUSSION.

a. Noise Impact. HUD notes that "Noise exposure may be a cause of adverse physiological and psychological effect," as well as a significant danger to the general quality of life.[3] Accordingly, restrictive Federal guidelines have been promulgated by HUD. Existing departmental policy for noise abatement and control at sites for new residential construction (single or multifamily) are as follows:

(1) Unacceptable if the CNR exceeds 115 or Zone 3.

(2) Discretionary when the CNR exceeds 100 or Zone 2, if suitable noise control features are included in the building design.

(3) Acceptable if the CNR does not exceed 100 or Zone 1.

An unacceptable, and possibly a discretionary noise condition, could result in the disapproval of a Federal Housing Administration (FHA) mortgage application.[3] Note that the Zone 3 areas (those areas receiving the greatest adverse noise impact) are confined to the immediate vicinity of the take-off/touchdown point. Although a CNR Zone 3 is relatively more adverse than a CNR Zone 2, the Zone 2 areas are still undesirable and incompatible with certain land uses according to HUD criteria.

b. Use of Statistical Data Base. The desired CNR contours are calculated for conditions of greatest noise exposure (worst case) in that two standard deviations above the mean A-weighted sound level of the aircraft noise emission data were used. The reasons for using this procedure are as follows:

(1) The CNR is a function of the maximum perceived noise level or dB(A).

(2) The procedure establishes a positive upper baseline limit insuring that 97.5 percent of the exposures are below the calculated values.

(3) The procedure accounts for the typical deviations resulting from "normal" flight operations at military installations. Thus, the CNR contours are constructed at the point where noise problems begin, rather than where 50 percent of the population may already be annoyed.

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[3] US Department of Housing and Urban Development Circular 1390.2, Noise Abatement and Control: Department Policy, Implementation, Responsibilities and Standards (4 August 1971).

c. Application of the Results.

(1) Noise levels from Army helicopter operations intruding into noise sensitive areas range between 77-83 dB(A). For a basis of comparison, a Swedish study reported that 50 percent of the population will be annoyed when a single overflight reaches 90 dB(A) providing take-off overflight frequency exceeds 36 to 63 operations per day.[17] A British study found that aircraft noise levels of 66 dB(A) were judged to be quiet and that noise levels of 105 dB(A) were judged to be noisy.[6] Another study reports listener judgments that show levels of 80 to 85 dB(A), as measured outdoors, falling between barely acceptable and unacceptable ratings.[10] These levels, however, were judged to be between the acceptable and barely acceptable categories after adjustment for typical building noise reduction due to transmission loss. Kryter reports that an average of 30 percent of the people living in a CNR 100 area will rate the noise environment as unacceptable.[13] In addition, it has been reported that noise from aircraft operations may interfere with some activities in the CNR 90-100 area.[12] Thus, aircraft noise levels exceeding 80 to 85 dB(A) or falling into a CNR 90-100 area are judged by many individuals to be noisy or annoying. Therefore, slight community annoyance due to helicopter noise may occur in residential areas near low altitude flight patterns.

(2) It is important to note that CNR zones are not rigid specifications, but are to be considered as guidelines only when assessing impact and response. The noise exposure calculations presented in this investigation should be used only as a planning guide and not as an attempt to predict the reaction of a community to noise except in the most general terms. In using the CNR analysis scheme, certain levels, flight paths, and atmospheric conditions were assumed. These facts also dictate that the reported CNR values be used only as guides to compatible land use planning and modification of operational procedures to reduce the magnitude of adverse noise exposure in the vicinity of McGuire VA Hospital. The CNR scheme should not be used to determine absolute geographical limits where significant

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[6] Theodore J. Schultz, "Noise Assessment Guidelines: Technical Background," US Department of Housing and Urban Development Report No. TE/NA 172 (1971).
[10] Dwight Bishop, "Judgments of the relative and absolute acceptability of aircraft noise," Journal of the Acoustical Society of America, 40, 108-122 (1966).
[12] Anon., "Aircraft Noise Impact: Planning Guidelines for Local Agencies," HUD Report TE/NA-472 (1972).
[13] Karl D. Kryter, The Effects of Noise on Man, Academic Press, New York (1970).
[17] R. Rylander et al., "Annoyance Reactions from Aircraft Noise Exposure," Journal of Sound and Vibration, 24(4), 419-444 (1972).

noise problems will occur. The CNR calculation procedure does not assure that every individual within designated noise impacted areas will find the noise objectionable, nor does it guarantee that all individuals living outside the specified areas will regard noise intrusion from airfield operations as acceptable. It is anticipated that some noise complaints will be made by people living outside calculated CNR 2 areas. In addition, the community reactions described in Table 1, Appendix B, are based on the average responses of certain communities that have been studied extensively. The actual reaction in a particular situation may be milder or stronger depending upon a number of factors relating to personal attitudes and community characteristics. The way in which these factors modify the reactions to the noise problem are not fully predictable in the present state-of-the-art (reference paragraph 1a).

d. Land Use. Noise sensitive land use is defined as that land upon which an on-going activity may be disrupted due to the intrusion of excessive noise into the environment. This disruption includes both interference with activities, such as telephone or person-to-person communication, due to the physical presence of the noise and general annoyance reactions on the part of the individuals living or relaxing within the noise sensitive areas. Noise sensitive areas include homes, schools, medical facilities, churches, theaters, community centers, offices, parks, etc.; while insensitive land areas with regard to noise include industrial facilities, commercial establishments, agricultural tracts of land, etc. Intrusion of noise into noise sensitive areas is undesirable and may result in a significant effect detrimental to both the health and welfare of personnel within these areas. Therefore, extreme care must be taken to insure that people located within noise sensitive land areas are not exposed to excessive environmental noise from military aircraft operations. In addition, it is advisable that aircraft operations be taken into account when planning future land use in the area of the McGuire VA Hospital helipad.

e. Blade Slap. Helicopter noise (typically the UH-1) is characterized by the occurrence of amplitude modulations. The modulations, termed "blade slap," subjectively observed by a listener on the ground as a very distinctive "throbbing" or "slapping" sound which is propagated in a forward direction and increases in level as the helicopter approaches overhead. Blade slap is generally predominant during (1) normal cruise where regions of air turbulence are encountered, (2) turning maneuvers, and (3) descent. This subjectively annoying phenomenon is not taken into account by any of the existing noise rating techniques.[18] [19] Conceivably, this lack of a

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[18] Charles L. Munch and Robert J. King, "Community Acceptance of Helicopter Noise: Criteria and Application," NASA CR-132430 (1974).

[19] Ernest G. Hinterkeuser and Harry Sternfeld, "Civil Helicopter Noise Assessment Study: Boeing Vertol Model 347," NASA CR-132420 (3 May 1974).

correction factor for blade slap is responsible for current aircraft noise rating procedures being less reliable in predicting the annoyance of helicopter noise than the noise generated from other types of aircraft. Thus, residents may be more annoyed by the noise than indicated by the contours of Figure 8 unless a special effort is made to minimize blade slap through a modification of helicopter flight procedures.[20]

f. Present Noise Abatement Procedures. Some aspects of the current air operational procedures serve quite well as noise abatement procedures. Flight over residential areas will be avoided and will thus minimize potential annoyance factors. The proposed flight altitudes over most of the flight path greatly reduce the potential noise impact. A very important factor reducing community annoyance is the absence of night operations (i.e., 2200-0700 hrs). Since annoyance due to noise is at its peak in the quiet evening and nighttime hours, the practice of no night flights is a very effective noise abatement procedure. The minimal number of operations anticipated for the helipad is also a very important noise abatement factor. All these factors contribute to a very acceptable noise environment.

g. Flight Altitudes. It is possible to reduce levels of noise impacting noise sensitive areas by flying at high altitudes near these areas. Generally, as aircraft altitude increases, the impacted land area underneath the flight path decreases. In the event that some noise complaints are received from the surrounding community, flying at a higher altitude will minimize annoyance without curtailment of flight operations. However, impacted areas may still remain near the helipad where aircraft are at very low altitudes.

h. Flight Patterns. Use of the Main Pattern is much preferred over the Alternate Pattern from a noise impact standpoint. More residences are located close to the flight path of the Alternate Pattern than to the path of the Main Pattern. Therefore, maximum utilization of the Main Pattern will greatly reduce the number of people impacted by the noise generated by military aircraft activity.

i. Time of Day. Individuals are generally less tolerant of aircraft noise at night than during the day. To effectively reduce annoyance, flights at night should continue to be prohibited.

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[20] J. B. Ollerhead, "Scaling Aircraft Noise Perception," Journal of Sound and Vibration, 26(3), 361-388 (1973).

j. Total Helicopter Activity. Community reactions to noise are generally based upon the cumulative effects of total activity. Thus, the greater the number of aircraft operations, the more annoying the total activity becomes. The CNR calculation procedure accounts for these cumulative effects of total activity. However, an increase in the number of operations by 100 percent, a rather small number of operations in this case, will change the calculated CNR value by three.

k. Meteorological Conditions. This report does not present a definitive analysis of the effects of meteorological conditions on the propagation of noise from aircraft operations. The meteorological effects of wind velocity and direction, temperature, humidity, barometric pressure, inversions, and cloud cover may well have an influence on the propagation and reception of noise. Temperature inversions, wind direction, and speed may, at times, increase the noise levels intruding into certain land areas, while decreasing it in other areas.

l. Noise Abatement. Flight procedures should be reviewed in order to establish minimum noise generating conditions. Adoption of approved noise abatement procedures will subsequently result in reduced noise levels intruding into residential and other noise sensitive areas. The following operational parameters to minimize noise intrusion can be investigated.[21]

(1) Reduction of operations to only those which are absolutely necessary.

(2) Establishment of increased minimum overflight altitudes.

(3) Avoidance of sharp turns to minimize blade slap.

(4) Utilization of high rates of climb consistent with safety requirements.

(5) Optimization of cruise speeds and rotor rpm for minimization of blade slap.

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[21] Jeffrey Goldstein and Roger Heymann, "Abatement of Helicopter Noise Through Operational and Land Use Controls," Proceedings of the National Noise and Vibration Control Conference, (ed) James Botsford, Chicago, Illinois (September 1973).

(6) Adjustment of descent and ascent rates to minimize blade slap.

(7) Restriction of flights over noise sensitive areas.

(8) Strict adherence to established flight procedure.

7. CONCLUSIONS. Based upon rotary-wing aircraft operations at the McGuire VA Hospital helipad, the following conclusions are drawn.

a. No CNR Zone 3 (unacceptable) noise conditions extend into land used for residential or other noise sensitive use.

b. No CNR Zone 2 (discretionary) conditions exist within noise sensitive areas within or surrounding the McGuire VA Hospital grounds.

c. Some slight annoyance may occur when UH-1 aircraft are at altitudes less than 600 ft AGL, as indicated by the calculated CNR 90 area extending into the hospital's spinal cord ward and 400 ft into residential areas.

d. There will be no adverse noise impact from helicopter aircraft ground activity.

8. RECOMMENDATIONS. In order to minimize annoyance from aircraft noise within noise sensitive areas, the following recommendations are made:

a. Continue to prohibit nighttime operations (2200-0700 hours).

b. Insure that future land use remains compatible with helipad activities. Restrict the development of CNR Zone 2 land areas to nonresidential and non-noise sensitive activities.

c. Insure that the operational parameters described in this report are not exceeded and that pilots do not deviate from established procedures.

d. Maintain preferred use of the Main Pattern over the Alternate Pattern.

e. Utilize OH-58 aircraft rather than UH-1 helicopters whenever possible.

f. Study the feasibility of employing noise abatement procedures as described in paragraph 6m.

g. Maintain an altitude of 1000 ft AGL or greater on the Sighting Pattern.

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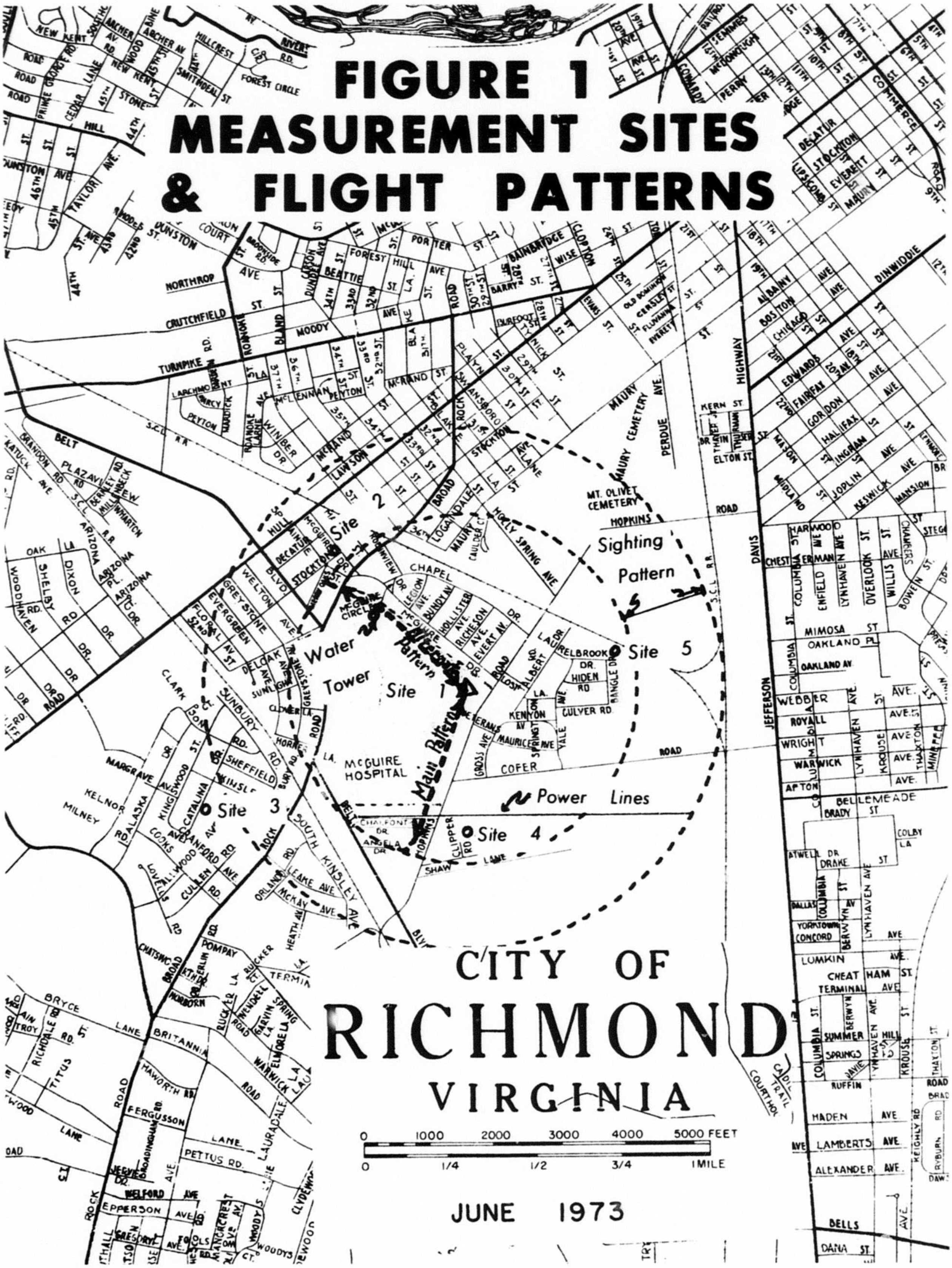
APPENDIX A

FIGURES

FIGURE 1 MEASUREMENT SITES & FLIGHT PATTERNS



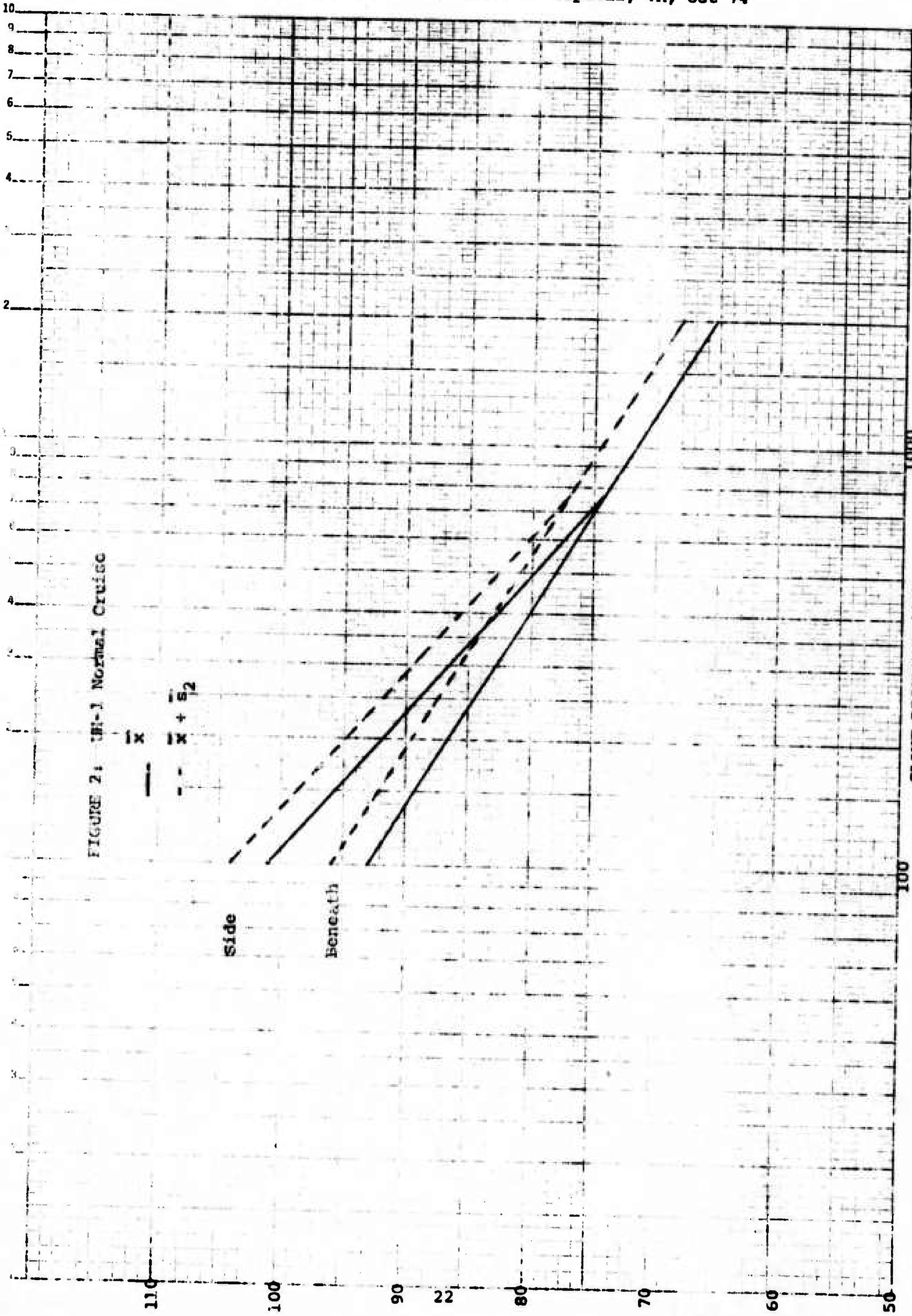


FIGURE 2: UH-1 Normal Cruise
— x̄
-- x̄ + s2
Side
Beneath
SLANT DISTANCE (ft)
100
1000
dB(A)
110
100
90
80
70
60
50

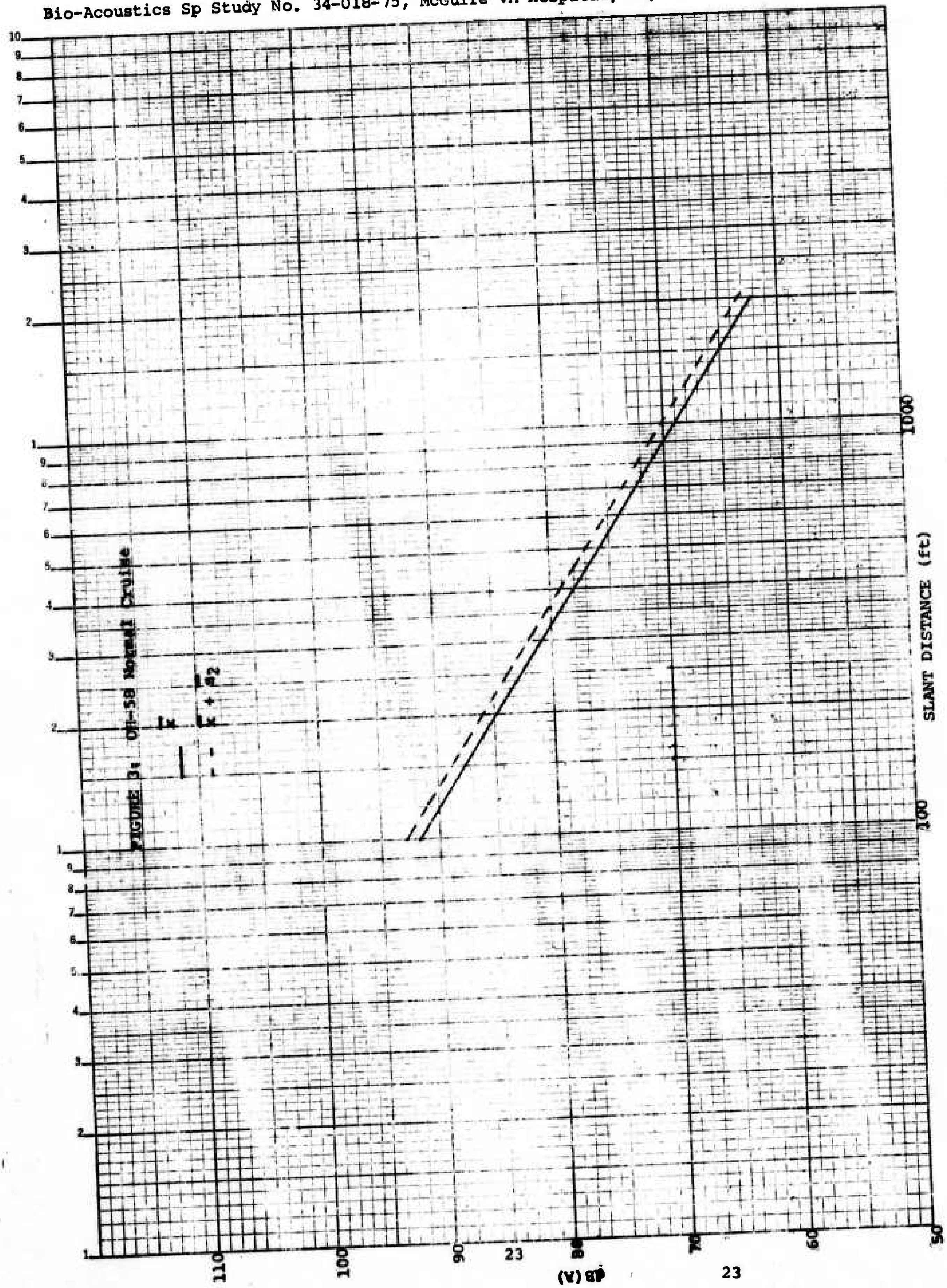
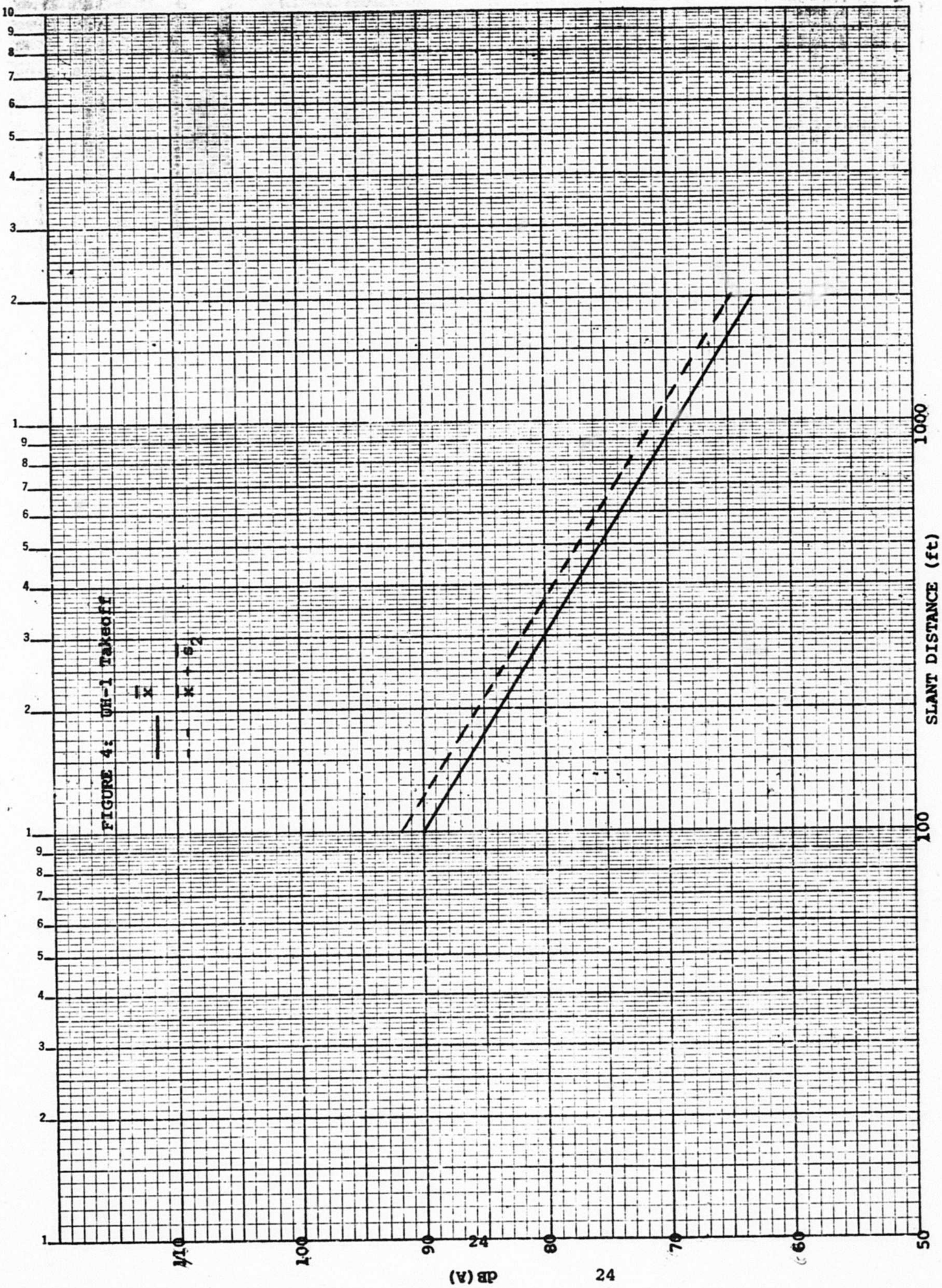


FIGURE 3: OH-58 Normal Cruise
$\bar{x}$
$\bar{x} + \sigma_2$
SLANT DISTANCE (ft)
100
1000
dB(A)
110
100
90
80
70
60
50

Bio-Acoustics Sp Study No. 34-018-75, McGuire VA Hospital, VA, Oct 74



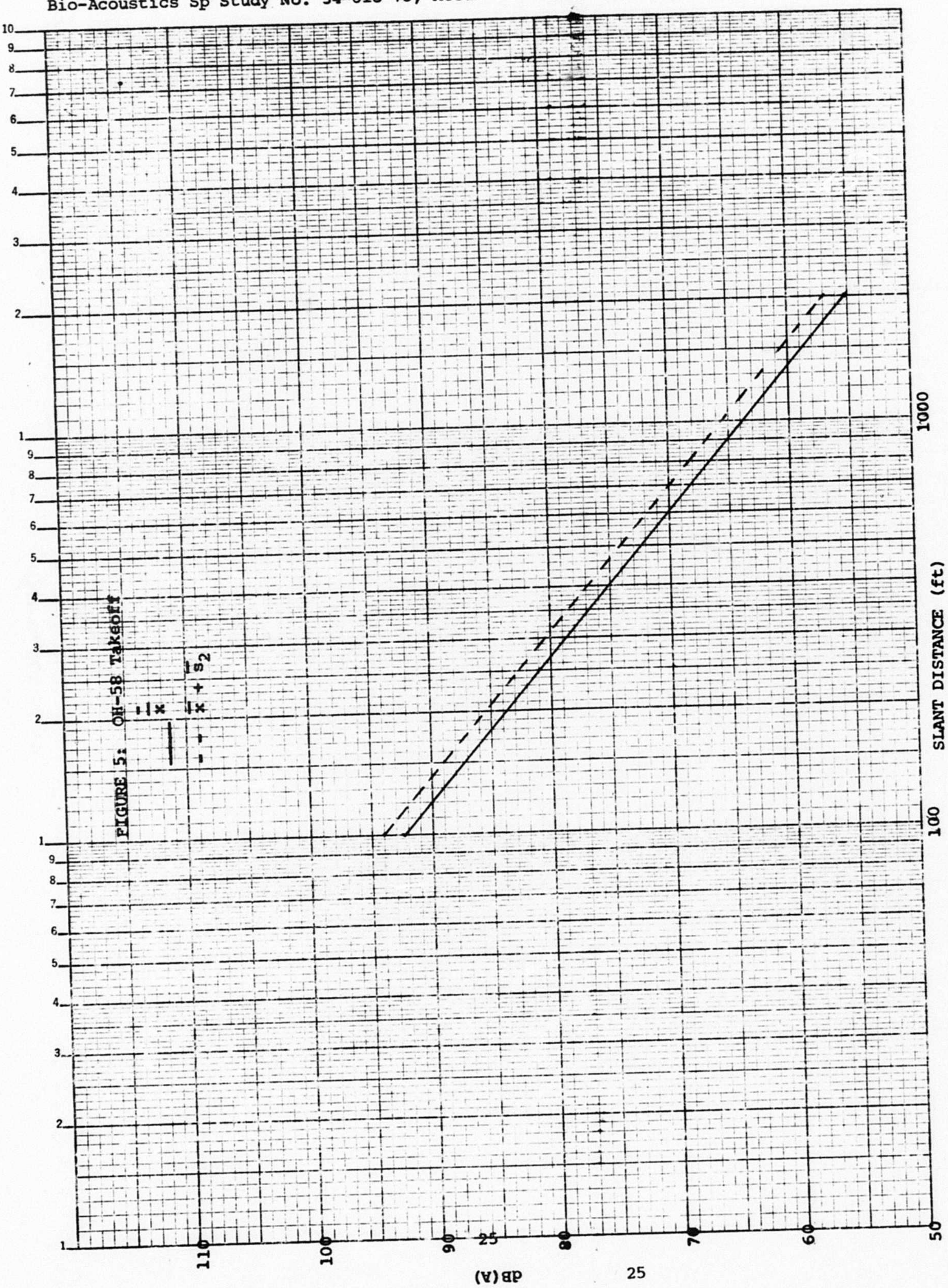
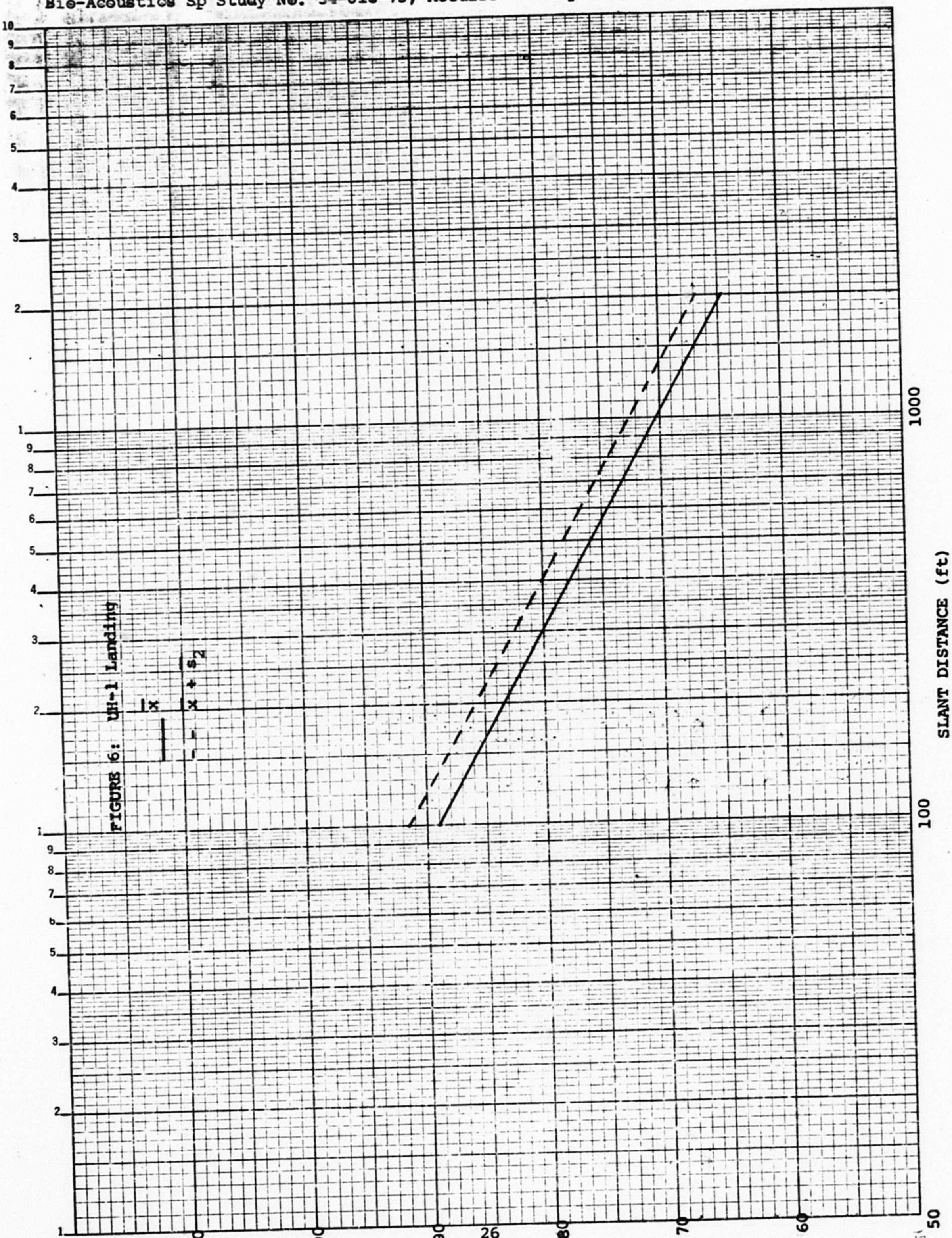


FIGURE 5: OH-58 Takeoff

Bio-Acoustics Sp Study No. 34-018-75, McGuire VA Hospital, VA, Oct 74



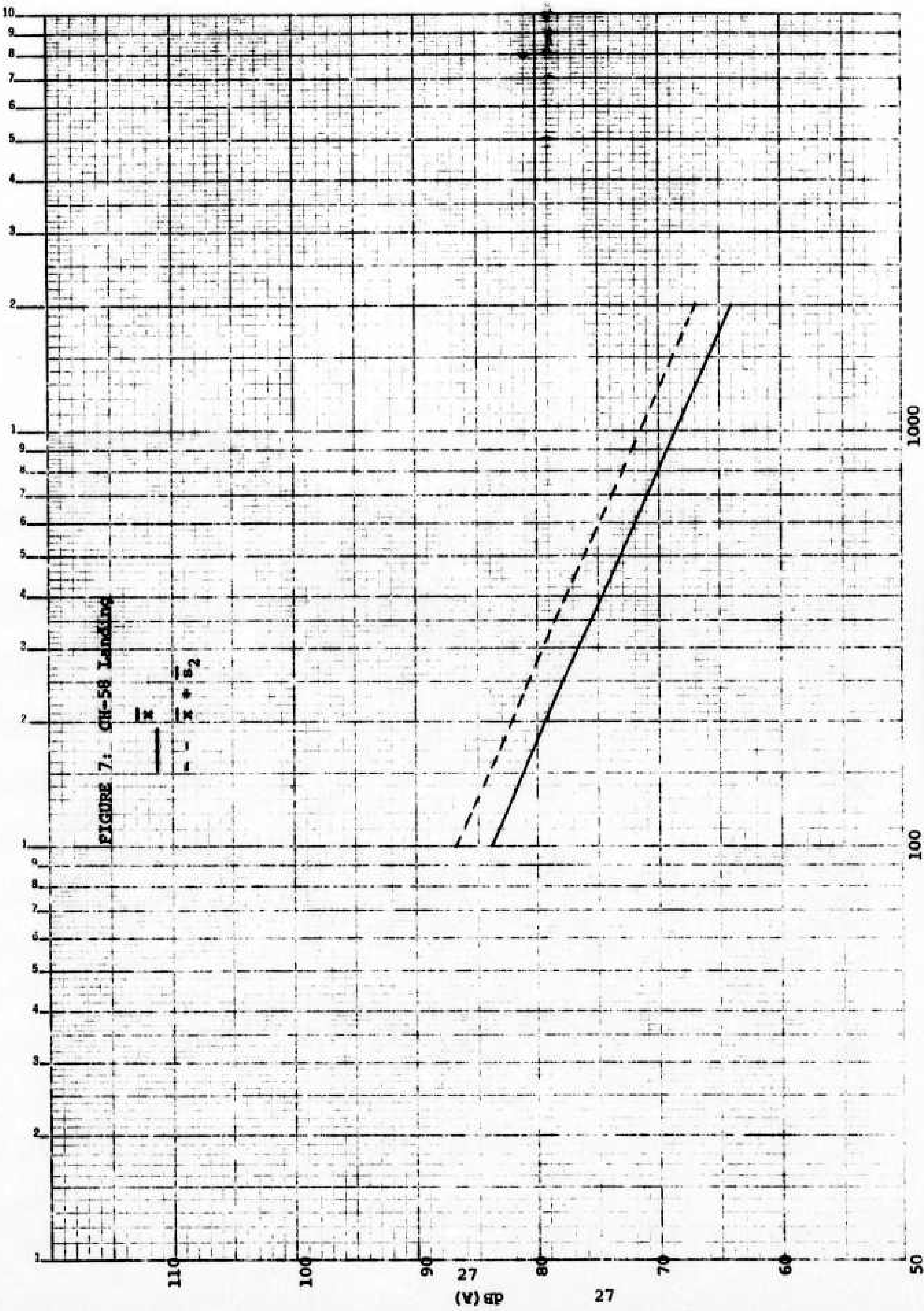


FIGURE 7: CH-53 Landing
$\bar{x}$
$\bar{x} + \bar{s}_2$
SLANT DISTANCE (ft)
50
100
1000
dB(A)
110
100
90
80
70
60

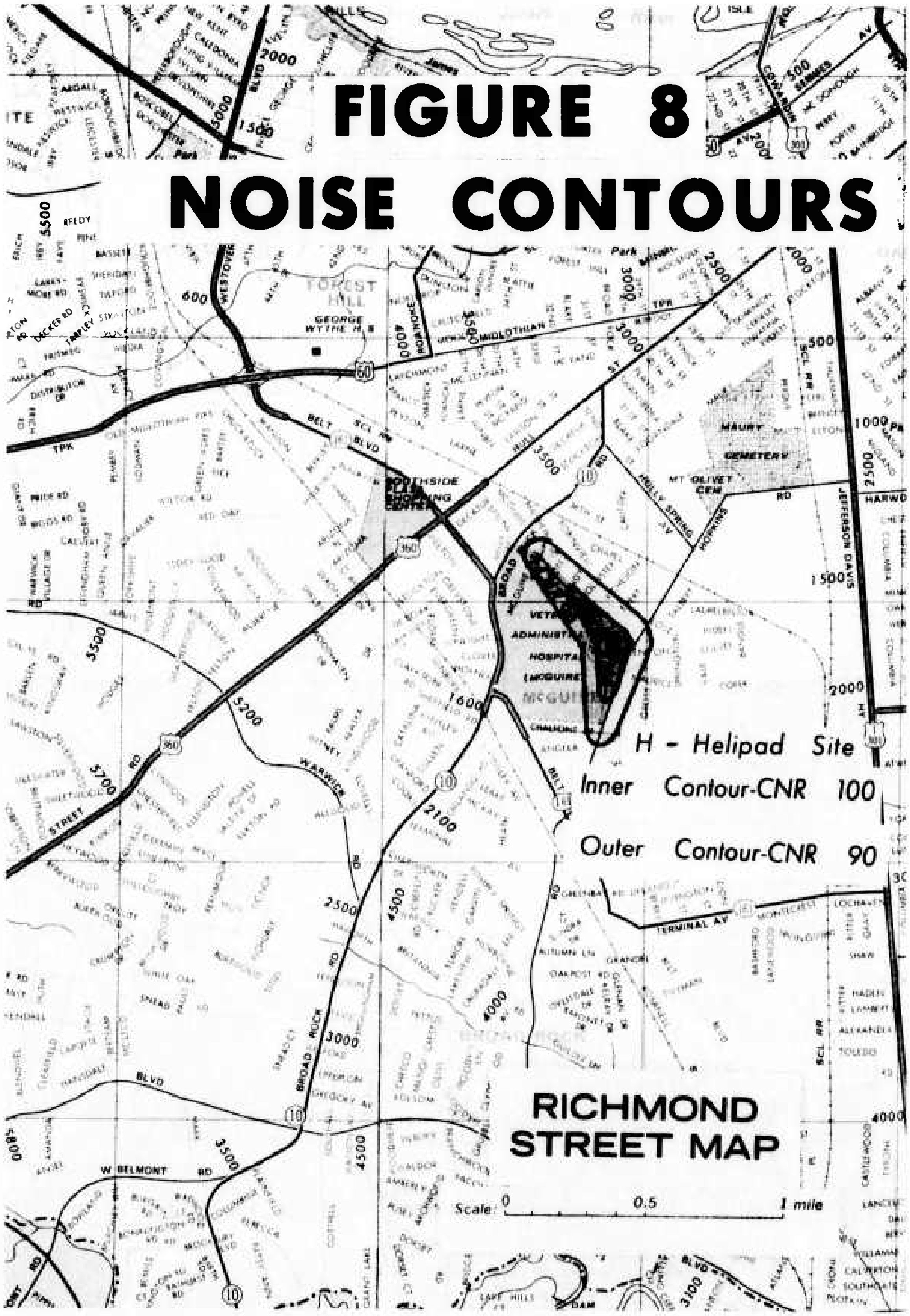


FIGURE 8
NOISE CONTOURS
H - Helipad Site
Inner Contour-CNR 100
Outer Contour-CNR 90
RICHMOND STREET MAP
Scale: 0 0.5 1 mile

APPENDIX B

TABLE 1
CHART FOR ESTIMATING RESPONSE OF RESIDENTIAL COMMUNITIES FROM COMPOSITE NOISE RATING*

Acceptability	Composite Noise Rating Take-offs/ Landings	Ground Operations	Zone	Description of Expected Response
Acceptable	Less than 100	Less than 80	1	Essentially no complaints would be expected. The noise may, however, interfere with certain activities of the residents.
Discretionary	100-115	80-95	2	Individuals may complain, perhaps vigorously. Concerted group action is possible.
Unacceptable	Greater than 115	Greater than 95	3	Individual reactions would likely include repeated, vigorous complaints. Concerted group action might be expected.

* HUD Circular 1390.2, August 4, 1971.

TABLE 2
CONVERSION OF CNR TO dB(A) VALUES

CNR	Aircraft [dB(A)] UH-1	OH-58
115	106.2	106.2
100	91.2	91.2
90	81.2	81.2

TABLE 3
AMBIENT NOISE LEVELS [dB(A)]

	L_{10}	L_{50}	L_{90}	$L_{10}-L_{90}$
Site 1	52	48	45	7
Site 2	56	50	48	8
Site 3	52.5	44	40	12.5
Site 4	51	45.5	43.5	7.5
Site 5	48	45	44	4

TABLE 4
OUTDOOR NOISE DATA FROM UH-1 OPERATIONS

Site	Outside Noise Level [dB(A)]	Ambient [dB(A)]
1	83	45-52
2	78	48-56
3	75	40-52.5
4	81	43.5-51
5	65	44-48

TABLE 5
LEVELS INTRUDING INDOORS

Site	Windows Open dB(A)	Windows Closed dB(A)
1	68	58
2	63	53
3	60	50
4	66	56
5	50	40

TABLE 6
CRITERIA OF DESIRABLE CONTINUOUS NOISE LEVELS
FOR INTERIOR SPACES

Activity	dB(A)	Condition
Hospital and Residences	34-47	Sleeping and Relaxing Conditions
Classrooms and Offices	38-47	Good Listening Conditions
Large Offices and Reception Areas	42-52	Moderately Good Listening Conditions

APPENDIX C

The following information is relative to the conduct of the data base studies:

a. Instrumentation. Bruel and Kjaer (B&K) precision sound level meters (Type 2204) tripod mounted with 1/2-inch microphones (Type 4134), and windscreens (Type UA 0075) were used for measuring aircraft noise. Tape recordings for laboratory analysis were made using a Uher magnetic tape recorder (Model 4200). Instrument calibration was performed in the field with B&K pistonphones (Type 4220). A reference calibration tone was put on each magnetic tape. Graphic level recordings of helicopter flyovers were made in the laboratory using a B&K graphic level recorder (Type 2305) with a pen speed of 16 millimeters/second to approximate a 0.5 second integration time. The magnetic tape recordings were fed into the graphic level recorder from the same magnetic tape recorder on which the data were collected. The data were A-weighted through a B&K measuring amplifier (Type 2606).

b. Level Flyovers. Level flyover measurements were conducted at Los Alamitos NAS, California, and Edgewood Area, Aberdeen Proving Ground (APG), Maryland. Data were gathered at two measurement stations 1000 ft apart directly under the flight paths.* Additional noise measurement stations were displaced 500 ft perpendicular from the mid-point of the line through the first two measurement stations. These latter two stations were used to quantify sideline noise data from helicopter flyovers. In addition to magnetic tape recordings of the noise data, a maximum root mean square (rms) sound level using the A-weighting network [dB(A)] of the sound level meter was observed at each measurement site. The sample size for both UH-1 and OH-58 level flyovers is included in Table 1. Aircraft operational parameters including altitude, airspeed, and power settings were recorded separately for each flyover. A summary chart of these parameters appears in Tables 2 and 3.

c. Take-offs and Landings. Noise measurements during take-offs and landings were also conducted at Los Alamitos NAS and Edgewood Area, APG. Three to four measurement stations one-half mile apart were spread out for 2 miles along the take-off and landing path. In addition to recording the data on magnetic tape, a maximum rms dB(A) sound level was observed at each measurement site for each flyover. The number of flyovers conducted for test noise measurements of the UH-1 during take-off and landing maneuvers is shown in Table 1. Helicopter operational parameters including altitude, airspeed, and power settings were recorded separately for each flyover. A summary chart of these parameters appears in Tables 2 and 3.

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* Flight procedures with helicopters are highly dependent upon local weather conditions and other air traffic in the immediate vicinity. Therefore, it is impossible for these craft to fly directly over the measurement stations on every run. Instead, these aircraft fly in corridors of variable dimensions.

d. Ground Run-ups. Helicopter ground run-ups for the UH-1 were conducted at an isolated area of Los Alamitos NAS. Measurements were made at 45°, 135°, 225°, and 315° at a radius of 200 ft around the test helicopter. Operational test conditions included a run-up from a shutdown condition to full take-off power. In addition to recording the data on magnetic tape, a maximum rms dB(A) sound level was observed at each measurement location.

TABLE 1
NUMBER OF MEASURED FLYOVERS FOR TEST HELICOPTERS

Operation	Sample Size UH-1	OH-58
Level Flyover	16	16
Take-off	8	11
Landing	7	11

TABLE 2
HELICOPTER OPERATIONAL PARAMETERS UH-1

Maneuver	Altitude (ft AGL)	Airspeed (knots)	Torque (lbs)	$\%N_1$ *
Level Flyover	250	80-85	23-25	89-90
	500	80	22-24	89-90
	1000	80	21-22	89-90
Take-off	60-150	50	25-27	†
	250-300	60	25-27	†
	420-500	70	25-27	†
	580-650	70	25-27	†
Landing	150-240	70	15	†
	450-500	90	15	†
	600-700	90	15	†

* The percent of maximum power available from the engine. Normally %N values range from 70-100 percent during operation.
† Not reported.

TABLE 3
HELICOPTER OPERATIONAL PARAMETERS OH-58

Maneuver	Altitude (ft AGL)	Airspeed (knots)	Torque (lbs)	$\%N_I$*
Level Flyover	250	90-95	56-58	92
	500	90-93	50-52	90-92
	1000	90-95	51-53	90-91
	1500	93-94	51-53	91
Take-off	150-200	60	55	90
	350-400	60	55	90
	500-600	60	55	90
	650-700	60	55	90
Landing	250-300	45	20	77
	600-700	45	20	77
	700	80	50	88
	700	80	50	88

* The percent of maximum power available from the engine. Normally %N values range from 70-100 percent during operation.

APPENDIX D

RELATION OF THE L_{dn} AND CNR DESCRIPTOR SYSTEMS

Adoption of the L_{dn} was based upon its many desirable characteristics for uniform noise ratings in all types of noise environments. The rating scheme (1) bears a meaningful relationship with the known effects of noise, (2) is applicable to the evaluation of long-term environmental noise, (3) uses a statistical approach to account for the whole time fluctuating pattern of noise, and (4) is simple, practical, accurate, and economical. L_{dn} is defined as the A-weighted equivalent continuous sound level during a 24-hour period with a 10 dB weighting applied to nighttime sound levels. This is expressed by the equation

$$L_{dn} = 10 \log \frac{1}{24} \left[15(10^{L_d/10}) + 9(10^{L_n+10/10}) \right]$$

where $L_d = L_{eq}$ for daytime (0700-2200 hours)

and $L_n = L_{eq}$ for nighttime (2200-0700 hours),

where L_{eq} is the mean noise energy level, defined as the level of the steady state continuous noise having the same energy as the actual time varying noise, expressed for an interval between two points in time t_1 and t_2 as:

$$L_{eq} = 10 \log \left(\frac{1}{t_2-t_1} \int_{t_1}^{t_2} \frac{p^2(t)}{p_o^2} dt \right)$$

where P(t) is the time varying sound pressure level and p_o is a reference pressure taken as 20 micropascals.

The L_{dn} may be indirectly related to CNR by the approximate equation

$$L_{dn} \approx \text{CNR} - 35$$

Thus, for example, the CNR 100 contour depicted in Figure 8 is approximately equivalent to an L_{dn} 65 equal noisiness contour. For most situations, this relationship is valid within $\pm$ 3 dB. The error associated with the translation between the L_{dn} and CNR rating schemes is due to differences between A-Weighted level and PNL, a duration correction, and differences in the nighttime correction. In addition, the ability of the L_{dn} measure to describe low-frequency, impulsive helicopter noise is questionable.

APPENDIX E
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